

Biology and demography of the diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae) on five cauliflower cultivars under laboratory conditions

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Abstract: 【Aim】 The diamondback moth, *Plutella xylostella* (L.), is globally regarded as most important pest of cruciferous plants. Due to increasing costs of spraying and destructive hazards on the environment, resistant cultivar is one of the perfect alternative methods to control *P. xylostella*. In the present study, due to lack of enough knowledge about resistance and susceptibility of different cultivars of cauliflower, we evaluated antibiosis resistance of some common cultivars and effects of different plant cultivars on potential of pest population growth. 【Methods】 In this research, life table parameters of *P. xylostella* were studied on five cauliflower cultivars including Smilla, White cloud, Buris, Galiblanca and Tokita under laboratory conditions of $25 \pm 2^\circ\text{C}$, $65\% \pm 5\%$ RH and 16L:8D photoperiod. 【Results】 The developmental time of immature stages ranged from 13.44 d on Smilla cultivar to 15.88 d on Buris cultivar. The highest fecundity of *P. xylostella* was observed on Buris cultivar. *P. xylostella* reared on Smilla cultivar had the highest intrinsic rate of increase (0.27 ± 0.02) and finite rate of increase (1.32 ± 0.13) and the lowest doubling time (2.50 d). 【Conclusion】 Therefore, Smilla cultivar is more susceptible than others to *P. xylostella* in the southern region of Tehran and the pest population can be quickly increased in the suitable conditions.

Key words: *Plutella xylostella*; demography; cauliflower; cultivars; life table parameters

1 INTRODUCTION

The diamondback moth (DBM), *Plutella xylostella* (L.) is one of the most destructive pests of cruciferous plants worldwide (Talekar and Shelton, 1993). Most of the Brassicaceae plants in the world such as broccoli, Brussels sprouts, cabbage, Chinese cabbage, cauliflower, kale, mustard, radish and turnip can be attacked by DBM (Talekar and Shelton, 1993; Capinera, 2001). The main damage of this pest is associated with larvae of different ages feeding underside surface of leaf, their chewing results in irregular patches of damage, though the upper leaf epidermis is often left intact. This pest on cauliflower preferred feeding flowers to leaves (Harcourt, 1986; Mitchell *et al.*, 1997). According to reports by Verkerk and Wright (1996), outbreaks of this pest in South Asia caused damage to more than 90% of farms. In Iran, Marzban and Baniamari (2005) reported severe outbreaks of this pest through 1999 in Tehran. Since

crops such as cauliflower are directly used by human, the use of pesticides in fields to control this pest is restricted (Sun *et al.*, 1986; Mota-Sanchez *et al.*, 2002; Mahmoudvand *et al.*, 2011). Also, due to increasing costs of spraying and destructive hazards on the environment, resistant cultivar is one of the perfect alternative methods to control *P. xylostella*. Effects of different plant cultivars on potential of pest population growth including the time of growth, prediction of a pest population size and age structure are reflected in the life table. One of the most important life table parameters is the intrinsic rate of increase, which is an appropriate measure in describing the growth rate of population. It can be used as an indicator of antibiosis resistance of *P. xylostella* and potential of population growth on different cultivars of cauliflower. In the present study, due to lack of enough knowledge about resistance and susceptibility of different cultivars of cauliflower, we evaluated antibiosis resistance of some common cultivars.

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2 MATERIALS AND METHODS

2.1 Insect rearing and plant growth

The initial population of *P. xylostella* was collected from the cauliflower field (located in the Shahed University), during the season. The stock culture of *P. xylostella* was initiated on different cauliflower cultivars and maintained at $25 \pm 1^\circ\text{C}$, $65\% \pm 5\%$ RH and 14L: 10D photoperiod in growth chamber. Five common cultivars of cauliflower including Smilla, White cloud, Buris, Galiblanca and Tokita were selected. Seeds of each cultivar were cultivated in small containers (flat wooden box) and after about five weeks (the 6 – 8 leaf stage), the plants were individually transferred to small plastic pots filled with sterilized soil and grown plants were used in the 10 – 12 leaf stage for experimentation purpose. The population of *P. xylostella* was reared on each cultivar for three generations under laboratory conditions. In order to obtain the same age eggs of DBM, cultivar leaves were placed inside oviposition cages containing 15 – 20 pairs of both sexes of DBM. After 10 – 12 h, leaves of each cultivar were taken from the cage and the eggs were picked up for experiments. The oviposition cage was a clear cubic Plexiglas's container (35 cm \times 35 cm \times 35 cm), with a fine nylon mesh installed on the top-side. The oviposition cage was transparent and cubic Plexiglas's container with a fine nylon mesh installed on the top-side. For survival of leaves, the end of leaves was placed in wet cotton. In this way, the leaf was fresh for 2 – 3 d. The leaves were replaced with fresh leaves everyday once. A small cotton strip soaked in 10% honey solution was used for feeding of adults.

2.2 Development of immature stages

Developmental duration of *P. xylostella* was determined on each cauliflower cultivar. At least 10 eggs of *P. xylostella* were taken from a surface of host plant using a small brush and placed individually on leaf of each cauliflower cultivar in 20 Petri dishes (8.0 cm in diameter). For survival of leaves, the base of each leaf was inserted in water soaked cotton to maintain its freshness. The leaves were replaced every two to three days once with fresh leaves. Lids of Petri dishes were covered with fine nylon mesh for aeration. The Petri dishes were placed in a growth chamber. The eggs were checked daily and their developmental stages were recorded. Development of larvae and pupae was observed in the growth chamber at similar conditions provided for eggs. The larvae were fed on fresh host leaves

provided from different cultivars. All larvae were checked and recorded daily for their developmental stages. Fresh foliage was provided every two to three days until the entire adults emerged or pupae died. Developmental duration was recorded for all immature stages.

2.3 Reproduction and population growth parameters

For the reproduction experiment, 15 pairs of male and female moths (each pair as one replicate) were transferred to transparent plastic cages (15 cm \times 8 cm \times 5 cm). For survival of leaves, the end of leaves was placed in wet cotton. Fresh foliage was provided every two to three days. The number of eggs laid by each female was recorded daily and monitoring continued until death of adults. Different parameters including pre-oviposition, oviposition and post-oviposition period, female longevity, and fecundity were determined. The intrinsic rate of increase (r_m), mean generation time (T), finite rate of increase (λ), doubling time (DT) and net reproduction rate (R_0) were calculated using the Carey formulae (Carey, 1993).

2.4 Data analysis

Differences in fecundity, longevity, and developmental duration were tested by ANOVA. The data were submitted to analysis of variance, and the observed means were compared using the Duncan's Multiple Range Test (DMRT, $\alpha = 0.05$) using SPSS 15.0 software (SPSS, 2006). To estimate the standard error of population growth parameter, Jack Knife method was employed (Meyer *et al.*, 1986).

3 RESULTS

The developmental duration of egg, four larval instars and pupal stages on the cauliflower cultivars is given in Table 1. There is significant difference between developmental duration for immature stages of *P. xylostella* reared on different cultivars ($P < 0.05$). According to grouping treatments, the minimum developmental duration of *P. xylostella* egg was obtained on Smilla cultivar (2.81 d). Significant difference was observed between Smilla with Buris, Galiblanca and Tokita cultivars, but no significant difference was observed with White cloud cultivar. Larval instar longevity varied significantly ($P < 0.05$), ranging from 6.92 to 8.58 d on Smilla and Buris cultivars, respectively. Significant difference was observed between the developmental duration of pupae on different cauliflower cultivars. The shortest developmental duration of pupae was observed on Smilla cultivar (3.20 d). The longest

total developmental duration was on Buris cultivar (15.88 d), and the shortest on Smilla cultivar (13.44 d).

The values related to the longevity, fecundity and oviposition periods of *P. xylostella* on different cultivars are given in Table 2. Statistical analysis showed that there was a significant difference among parameters of oviposition period and female longevity

of *P. xylostella* on five cultivars ($P < 0.05$). The highest oviposition period of *P. xylostella* was on the Galiblanca cultivar (17.15 d). Female moths had a longer longevity on White cloud, Buris and Galiblanca cultivars than on the other two cultivars. There was no significant difference observed among the pre-oviposition and post-oviposition periods and fecundity of females reared on all the five cultivars.

Table 1 Developmental duration of immature stages of *Plutella xylostella* on different cauliflower cultivars

Developmental stage	Developmental duration (d)				
	Smilla	White cloud	Buris	Galiblanca	Tokita
Egg	2.81 ± 0.05 b	2.91 ± 0.04 ab	3.03 ± 0.05 a	2.96 ± 0.04 a	3.00 ± 0.04 a
1st instar larva	1.74 ± 0.06 a	1.80 ± 0.09 a	1.86 ± 0.08 a	1.82 ± 0.08 a	1.84 ± 0.08 a
2nd instar larva	2.00 ± 0.76 b	2.08 ± 0.10 b	2.48 ± 0.11 a	2.10 ± 0.12 b	2.20 ± 0.11 ab
3rd instar larva	1.30 ± 0.46 b	1.34 ± 0.07 b	1.72 ± 0.06 a	1.42 ± 0.07 b	1.68 ± 0.07 a
4th instar larva	1.88 ± 0.52 d	2.06 ± 0.10 cd	2.52 ± 0.10 a	2.16 ± 0.09 bc	2.36 ± 0.11 ab
Total larval stage	6.92 ± 1.14 c	7.28 ± 0.19 bc	8.58 ± 0.18 a	7.50 ± 0.20 b	8.08 ± 0.20 a
Pre-pupa	0.52 ± 0.01 b	0.54 ± 0.20 ab	0.60 ± 0.03 a	0.55 ± 0.02 ab	0.59 ± 0.03 a
Pupa	3.20 ± 0.07 b	3.42 ± 0.10 ab	3.68 ± 0.11 a	3.44 ± 0.10 ab	3.52 ± 0.10 a
Total immature stage	13.44 ± 0.20 d	14.15 ± 0.23 c	15.88 ± 0.19 a	14.45 ± 0.22 c	15.19 ± 0.22 b

Data (means ± SE) in the same row followed by different letters are significantly different according to Duncan's multiple range test ($P \leq 0.05$). The same for the following tables.

Table 2 Longevity, fecundity and oviposition periods of female adults of *Plutella xylostella* reared on five cauliflower cultivars

Cultivars	Longevity (d)	Fecundity (number of eggs laid per female per day)	Oviposition period (d)		
			Pre-oviposition	Oviposition	Post-oviposition
Smilla	27.18 ± 1.30 ab	220.73 ± 23.49 a	13.82 ± 0.30 a	11.73 ± 1.21 bc	0.64 ± 0.20 a
White cloud	30.00 ± 1.40 a	195.31 ± 19.88 a	14.69 ± 0.65 a	17.08 ± 2.11 a	0.62 ± 0.27 a
Buris	29.92 ± 1.28 a	227.23 ± 15.61 a	14.62 ± 0.35 a	14.77 ± 1.41 ab	0.64 ± 0.24 a
Galiblanca	30.69 ± 0.95 a	185.23 ± 16.44 a	15.38 ± 1.15 a	17.15 ± 1.04 a	0.54 ± 0.27 a
Tokita	25.92 ± 1.41 b	170.85 ± 21.94 a	14.46 ± 0.54 a	9.85 ± 1.63 c	1.46 ± 0.50 a

As shown in Table 3, there is significant difference between intrinsic rates of increase (r_m) of *P. xylostella* on five cauliflower cultivars. The value of intrinsic rate of increase of *P. xylostella* on Smilla cultivar (0.27 ± 0.02) was significantly bigger than other cultivars. The lowest value of intrinsic rate of increase of *P. xylostella* was calculated on Galiblanca cultivar (0.22 ± 0.03). Statistical analysis showed that there were no significant differences between net reproductive rate (R_0) of *P. xylostella* on the studied cultivars. This parameter indicates high reproduction ability and effective individuals in the generation. The highest finite rate of increase and lowest doubling time of *P. xylostella* were observed on Smilla cultivar (1.32 and 2.50 d, respectively). *P. xylostella* populations on the Galiblanca cultivar had lowest finite rate of increase and highest doubling time (1.28 and 2.84 d,

respectively).

4 DISCUSSION

Results of this research showed that the host plant had significant effects on developmental time, longevity and fecundity of *P. xylostella*. So these parameters can be influenced by the food and its quality. Also other researchers have pointed out effects of host plants on the biological characteristics of *P. xylostella* (Syed and Abro, 2003; Jahan *et al.*, 2013; Hasanshahi *et al.*, 2013b, 2013c).

The longest and shortest developmental duration for immature stages were recorded on Buris and Smilla cultivars (15.88 and 13.44 d, respectively). Golizadeh *et al.* (2009) studied the influence of various cruciferous host plants on

Table 3 Population growth parameters of *Plutella xylostella* on five cauliflower cultivars

Cultivars	Parameter				
	Net reproductive rate (R_0)	Intrinsic rate of increase (r_m)	Finite rate of increase (λ)	Doubling time (DT)	Mean generation time (T)
Smilla	111.59 ± 17.20 a	0.27 ± 0.02 a	1.32 ± 0.13 a	2.50 ± 0.25 b	16.97 ± 1.70 b
White cloud	96.80 ± 12.37 a	0.25 ± 0.03 b	1.29 ± 0.17 ab	2.73 ± 0.42 ab	18.03 ± 2.49 ab
Buris	113.69 ± 19.84 a	0.25 ± 0.04 b	1.29 ± 0.18 ab	2.73 ± 0.37 ab	18.62 ± 2.60 a
Galiblanca	92.53 ± 13.89 a	0.22 ± 0.03 b	1.28 ± 0.18 b	2.84 ± 0.42 a	18.57 ± 2.62 a
Tokita	85.42 ± 14.60 a	0.25 ± 0.03 b	1.28 ± 0.17 b	2.83 ± 0.44 a	18.16 ± 2.68 ab

development of *P. xylostella*. They found that *P. xylostella* completed its larval and pupal development in the shortest time on Kohlrabi. They also reported that larval period on cauliflower was 7.38 d, similar to our findings (Table 1). In this study the longevity of *P. xylostella* was calculated on different cultivars between 25.92 and 30.69 d. Based on studies by Wakisaka *et al.* (1992), the male and female adult longevity of *P. xylostella* was reported on Brussels sprouts (12.21 and 11.08 d, respectively). Total fecundity in the study ranged from 170.85 to 227.23 eggs on Tokita cultivar and Buris cultivar, respectively (Table 2). Shaila (2007) noted that the fecundity of the pest was equal to 193.4 eggs and larval period was 12.1 d greater than the values calculated in present study. It appears that difference between results of this study and that of other researchers are probably due to difference in cultivar, quality of tested host plants, growing conditions and populations of *P. xylostella* (Umeya and Yamada, 1973; Sarnthoy *et al.*, 1989; Shirai, 2000; Awmack and Leather, 2002).

Findings from this study are comparable with results from other researchers that showed value of the intrinsic rate of increase (r_m) of *P. xylostella* on tested cauliflower cultivars is more than wild crucifer and less than leaf cabbage. Ayalew *et al.* (2006) calculated the highest r_m values and finite rate of increase (λ) and the lowest doubling time (DT) on cabbage equal to 0.31 (females/female/day), 1.37 and 2.20 d, respectively. Also, the lowest r_m values and net reproductive rate (R_0) was calculated on wild crucifer equal to 0.136 (females/female/day) and 27.52 (females/female/generation), respectively (Wakisaka *et al.*, 1992).

Statistical variables including fertility and intrinsic rate of natural increase are valid criteria for determining *P. xylostella* performance. These population parameters are comprehensive and important that can be used as indicators of antibiosis resistance and growth potential of populations of *P. xylostella* on different cauliflower cultivars. In other words, each cultivar that pest population on it have lower rate of intrinsic rate of increase and reproductive has higher

resistance than other cultivars (Zarpas *et al.*, 2006). According to results of this study especially r_m values, Galiblanca cultivar has stronger resistance to *P. xylostella*. Other researchers showed that Galiblanca cultivar is one of the resistant cultivars to the diamondback moth in field conditions (Hasanshahi, 2012; Hasanshahi *et al.*, 2013a). In this study, due to the high intrinsic rate of increase, finite rate of increase and the lowest doubling time, Smilla cultivar is most suitable cultivar for *P. xylostella* population growth. On the other hand, Galiblanca cultivar with the lowest intrinsic rate of increase, finite rate of increase and the high doubling time will reduce the population of *P. xylostella* on cauliflower. Therefore, Galiblanca cultivar can be used in pest management program as important and effective strategy for *P. xylostella* control and reducing pesticide use. However, since the present research was conducted under laboratory conditions, to get more accurate results, further study is needed to be performed in field conditions and on different developmental stages of host plant.

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室内条件下小菜蛾在五种花椰菜栽培种上的生物学和种群统计

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摘要:【目的】小菜蛾 *Plutella xylostella* (L.) 是全球十字花科植物上最重要的害虫。由于施药成本的增加以及对环境的破坏性危害,抗性栽培种成为控制小菜蛾的理想选择。本研究中,鉴于对花椰菜不同栽培种的抗感性缺乏充分的了解,我们评价了几个常见栽培种的抗性以及不同植物栽培种对害虫种群增长潜力的影响。【方法】在 $25 \pm 2^\circ\text{C}$, RH $65\% \pm 5\%$ 和光周期 16L:8D 的室内条件下,研究了小菜蛾 *P. xylostella* 在 5 种花椰菜栽培种 (Smilla, White cloud, Buris, Caliblanka 和 Tokita) 上的生命表参数。【结果】小菜蛾幼期发育历期变化范围从 Smilla 上的 13.44 d 至 Buris 上的 15.88 d。在 Buris 上观察到最高的生殖力。在 Smilla 上饲养的小菜蛾种群内禀增长率 (0.27 ± 0.02) 和有限增长率 (1.32 ± 0.13) 最高,而倍增时间最短 (2.50 d)。【结论】因此,与其他栽培种相比,在伊朗南部 Smilla 更适合小菜蛾存活和繁殖,在条件合适和天敌缺乏时该害虫的种群能快速增长。

关键词: 小菜蛾; 种群统计; 花椰菜; 栽培种; 生命表参数

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